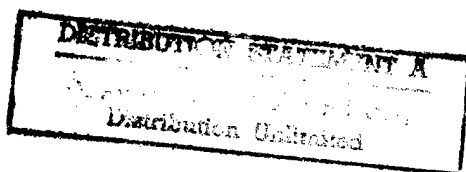
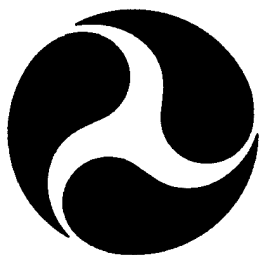


Report No. CG-D-18-98

Testing of an Ignitability Standard for Bedding Components

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Final Report
July 1998

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National Technical Information Service, Springfield, Virginia 22161

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Marine Safety and Environmental Protection, (G-M)
Washington, DC 20593-0001

19980807 078


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1. Report No. CG-D-18-98		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Testing of an Ignitability Standard for Bedding Components				5. Report Date July 1998	
				6. Performing Organization Code Project No.: 3308.1.81	
7. Author(s) Louis Nash				8. Performing Organization Report No. R&DC 09/97	
				10. Work Unit No. (TRAIS) SHRD Report No. 112	
9. Performing Organization Name and Address U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096				11. Contract or Grant No.	
				13. Type of Report and Period Covered Final Report	
12. Sponsoring Agency Name and Address U.S. Department of Transportation United States Coast Guard Marine Safety and Environmental Protection, (G-M) Washington, DC 20593-0001				14. Sponsoring Agency Code Commandant (G-MSE)	
15. Supplementary Notes The Headquarters project officer was Mr. Klaus Wahle, Lifesaving and Fire Safety Division. Peer reviewer was LDCR Rich Matters. The USCG Research and Development Center point of contact is Louis Nash at 860-441-2763.					
16. Abstract (200 words or less) This report describes testing of an ignitability standard for bedding aboard commercial vessels as proposed at the International Maritime Organization (IMO). The objectives were to identify weaknesses, to qualitatively gauge the effectiveness of the standard, and to evaluate performance of domestic products. A version of the proposed standard was adopted as IMO Resolution A.688(17), Fire Test Procedures for Ignitability of Bedding Components. The adopted version of the standard is only addressed in this report with regard to the pass/fail criteria. The proposed standard had three ignition sources: cigarette covered by a cotton sheet, cigarette covered by a cotton wool pad, and a match flame (6.5 mm tube burner). The cotton wool pad and cotton sheet were 150 mm square. Test samples were made by cutting mattresses, blankets, and sheets into 450 mm by 350 mm sections; pillows were tested whole. The duration of the exposure to the ignition source is complete consumption of the cigarette and 20 seconds for the flame. The sample is considered to fail if it demonstrates progressive smoldering or flaming ignition. Progressive smoldering covers several responses including length of char. The proposed test method was followed with minor exceptions of washing the samples and using longer cigarettes. The bedding components were nine inner spring mattresses, four pillows, one pillow case, five sheets, and two synthetic blankets. The results of the testing are presented in five sections. The first section addresses how U.S. materials fared under the proposed test protocol. The second section addresses the effect of washing the sheets. The third section presents the results of testing combinations of bedding components. The fourth section addresses the appropriateness of the cotton-wool pad as a cover for the cigarette. The fifth section addresses the appropriateness of mineral wool as a substrate.					
17. Key Words Fire Safety, Engineering Methodology, Ship Fire, Risk Analysis, Flame Movement, Fire Hazard			18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.		
19. Security Classif. (of this report) UNCLASSIFIED		20. SECURITY CLASSIF. (of this page) UNCLASSIFIED		21. No. of Pages	
				22. Price	

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

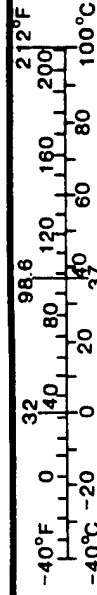


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ACKNOWLEDGMENTS

This work was sponsored by the Office of Marine Safety and Environmental Protection.

The author wishes to acknowledge Marjorie M. Murtagh who was then Chief, Fire Protection Section, Ship Design Branch, Marine Technical and Hazardous Materials Division of the Office of Marine Safety, Security and Environmental Protection. Ms. Murtagh provided impetus and support of the project as the U.S. delegate to the SubCommittee on Fire Protection during the development of the work.

The author wishes to acknowledge Klaus Wahle of the Office of Design and Engineering Standards, Standards Directorate, Organization of Marine Safety and Environmental Protection. Mr. Wahle provided technical oversight of the project as the U.S. member of the Ad Hoc Working Group on Fire Test Procedures.

The author wishes to acknowledge Denise Bailly who spent many hours burning holes in mattresses and bedding in executing this project.

EXECUTIVE SUMMARY

This report describes testing of an ignitability standard for bedding, including mattresses, aboard commercial vessels as proposed at the International Maritime Organization (IMO). The objectives of the testing were to identify areas where the standard could be improved, to qualitatively gauge the effectiveness and appropriateness of the standard, and to evaluate how domestic products would fare under the standard. A modified version of the proposed standard was adopted as IMO Resolution A.688(17), Fire test procedures for ignitability of bedding components, in November, 1991. The adopted version of the standard is only addressed with regard to the pass/fail criteria.

The proposed standard had three ignition sources: cigarette covered by a cotton sheet, cigarette covered by a cotton wool pad, and match flame. The latter was simulated by a 6.5 mm tube burner, fueled by either butane or propane, to produce a small flame to which a sample would be exposed for 20 seconds (Propane was used in this study). The cotton wool pad and cotton sheet were 150 mm square.

Test samples were made by cutting mattresses, blankets, and sheets into 450 mm by 350 mm sections. Pillows were tested whole. Mattresses and pillows were placed directly on the test stand; sheets and blankets were laid over a 50-mm thick layer of mineral wool which is placed on the test stand.

Two test samples were used for each ignition source. The duration of the exposure to the ignition source is complete consumption of the cigarette and 20 seconds for the flame. The sample is considered to fail if it demonstrates progressive smoldering or flaming ignition.

Progressive smoldering covers several responses to the ignition source. It includes the length of char that is commonly used in the United States. In this report, length of char is reported separately and is measured from the cigarette. In IMO Resolution A.688(17), the length of char is measured from the edge of the cotton-wool pad. The other responses included in progressive smoldering indicate a sustained or growing non-flaming combustion.

The proposed test method (Appendix A) was followed with minor exceptions. Flame retardant samples were not cleansed three times before testing as the goal was to test the method, not to accept the product. The legs of the test stand were shortened to fit the test stand into a fume hood. This shortened stand does comply with final version of the standard (IMO Res. A.688(17)). The cigarettes used in this study were 9 mm longer than the maximum length in the proposed standard. The expected effect of the longer length is that these tests would be slightly more severe.

The selection of bedding components for testing was initially made by canvassing a half dozen hotels and motels to determine

their sources of supplies. Emphasis was placed on mattresses as they are the largest component and are already subjected to a federal fire test standard, 16 CFR 1632. Blankets were given the least attention as wool had fared very well in previous upholstered furniture testing (See McLain, 1988). The initial selection was augmented by choosing specimens from the Federal Stock System to provide a wider selection. The final selection of components was nine inner spring mattresses, four pillows, one pillow case, five sheets, and two synthetic blankets.

All test specimens passed the ignition source of cigarette covered by fabric. This ignition source was not included in the adopted version, IMO Res. A.688(17).

There is no apparent relationship between resistance to the smoldering and flaming ignition sources. Four out of the five mattresses that met the criteria in IMO Res. A.688(17) for the cigarette covered by the cotton wool pad were ignited by the flame. Three out of the four mattresses that met the criteria in IMO Res. A.688(17) for the flame failed when tested to cigarette covered by the cotton wool pad. Only one out of the nine mattresses passed both criteria.

One of the four pillows met the requirements of the proposed standard. One out of the five sheets met the requirements of the proposed standard. Neither of the two blankets met the criteria. The results are the same under the revised criteria of IMO Res. A.688(17). For the samples tested, the discriminating test is the flaming ignition source.

The test protocol appears to have some effect based on very limited testing of combinations of bedding components. The testing was to ensure that the standard was adequate. Using the mattress meeting the proposed standard (mattress #8) and a cotton/polyester sheet (sheet #1), the addition of a sheet between the cigarette and mattress resulted in larger char areas but did not progress to sustained combustion. Four cases of cigarettes between a mattress and pillow that met the proposed standards (mattress #8 and pillow #1) resulted in smaller char areas than observed when tested to the standard.

For exposure to flame, the mattress meeting the standard provides some benefit even though the covering item may not meet the standard. The five sheets and two blankets were tested over two mattresses. For the mattress not resistant to flame, the combination failed even when tested with sheet #5 which met the standard (with the exception of blanket #2). The combination of both a mattress (#8) and a sheet (#5) meeting the proposed standard proved resistant to the flame. For the other sheets and blankets, the results were mixed when tested over mattress #8.

Using the criteria in IMO Res. A.688(17), all test specimens that failed due to length of char under the proposed protocol would have passed the cigarette covered by a cotton wool pad. The permissible length of char was increased to be 25 mm from the edge of the cotton wool pad instead of from the cigarette.

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INTRODUCTION

This report describes testing of a proposed ignitability standard for bedding, including mattresses, aboard commercial vessels. The objectives of the testing were to identify areas where the standard could be improved, to qualitatively gauge the effectiveness and appropriateness of the standard, and to evaluate how domestic products would fare under the standard.

The information produced was used by Coast Guard Headquarters' personnel to formulate a U.S. position in regards to the standard for the 35th meeting of the International Maritime Organization's SubCommittee on Fire Protection. At that meeting, the SubCommittee modified the proposed standard in response to input by the United States and other countries. The revised standard is only addressed in this report with regard to the pass/fail criteria.

BACKGROUND

The International Maritime Organization (IMO) is an agency of the United Nations. IMO's purpose is to develop standards to improve safety at sea and prevent pollution of the oceans. It was established in 1958 under the name of the Intergovernmental Maritime Consultative Organization (IMCO). The name was changed in 1982.¹

IMO's governing body is an assembly of representatives from 134 member countries and two associative members. One of five committees supporting the assembly is the Maritime Safety Committee. That committee is supported by 10 technical subcommittees; one of which is the SubCommittee on Fire Protection. That subcommittee has set up the Ad Hoc Working Group on Fire Test Procedures to evaluate and propose fire test methods and acceptance criteria.

The U.S. Coast Guard represents the United States at meetings of the Maritime Safety Committee and its subcommittees.

Industry input in the development of U.S. positions involving fire protection was provided through the SOLAS Working Group on Fire Protection. This is one of 12 domestic working groups of the Shipping Coordinating Committee, a federal advisory committee formed by the Department of State in 1958.

A key to understanding the development of an IMO standard is that the SubCommittee on Fire Protection and its working groups generally meet for one week per year. The first mention of a need for an ignition test of mattresses and bedding was in

¹ For an overview of IMO and the involvement of the U.S. Coast Guard and industry in IMO, see Thompson (1990)

discussion of the Ad Hoc Working Group on Fire Test Procedures during the thirty-first session of the SubCommittee on Fire Protection.² The working group was evaluating an upholstered furniture ignition test (BS-5852: Part 1) which had just been accepted by ISO. Efforts were ongoing in United Kingdom and Norway to apply the methodology to bedding.

At the thirty-second session, the SubCommittee on Fire Protection issued a call for member countries to submit or circulate their standards for bedding. At the thirty-third session, the working group had before it three standards: 16 CFR 1632 submitted by the United States, a United Kingdom standard, and a draft NordTest method (NTFire 037: Bedding components: Ignitability). As interlaboratory work was already being undertaken for all three methods, the working group agreed to submit a recommendation at the next session. They also submitted an upholstered furniture ignition test method to the SubCommittee on Fire Protection for approval.

At the thirty-fourth session, the working group decided that a test method must address both ignition by flame and cigarette. The U.S. standard 16 CFR 1632 only address ignition by cigarette. The working group drafted a proposed method for bedding based on the NordTest method and requested comments.³ The testing covered by this report was in response to that request.

At the thirty-fifth session, the working group revised the proposed method and submitted it to the SubCommittee on Fire Protection for approval. One of the main revisions was the elimination of one of the two cigarette ignition sources. The subcommittee approved the test method and forwarded it to the Maritime Safety Committee for approval. The proposed method was finally adopted as IMO Resolution A.688(17), Fire test procedures for ignitability of bedding components, in November 1991.

EXPERIMENTAL

Summary of Proposed Test Method

The following is a summary of the proposed test method as used for testing; the complete version is in Appendix A. The

² The Ad Hoc Working Group on Fire Test Procedures met from: 24 to 26 February 1986 for the thirty-first session, 26 to 29 January 1987 for the thirty-second session, 15 to 19 February 1988 for the thirty-third session, 27 February to 3 March 1989 for the thirty-fourth session, and 2 to 4 July 1990 for the thirty-fifth session.

³ Proposed method was contained in Annex 6 of FP34/23 and is reproduced in Appendix A. The NordTest method (NTFire 037: Bedding components: Ignitability) was approved by NordTest in September 1989.

test method had three ignition sources: cigarette covered by a cotton sheet, cigarette covered by a cotton wool pad, and match flame. The latter was simulated by a 6.5 mm tube burner, fueled by either butane or propane, to produce a small flame to which a sample would be exposed for 20 seconds. The cotton wool pad and cotton sheet were 150 mm square.

Test samples were made by cutting mattresses, blankets, and sheets into 450 mm by 350 mm sections. Mattresses were cut such that the cut sides were sewed shut using a flap of the covering layers. For mattresses, the cut ends were sewn shut. Pillows were tested whole. Mattresses and pillows were placed directly on the test stand (see Figure 1). Thin samples such as sheets and blankets were laid over a 50-mm thick layer of mineral wool which is placed on the test stand.

Two test samples were used for each ignition source. The duration of the exposure to the ignition source is complete consumption of the cigarette and 20 seconds for the flame. The sample is considered to fail if it demonstrates progressive smoldering or flaming ignition.

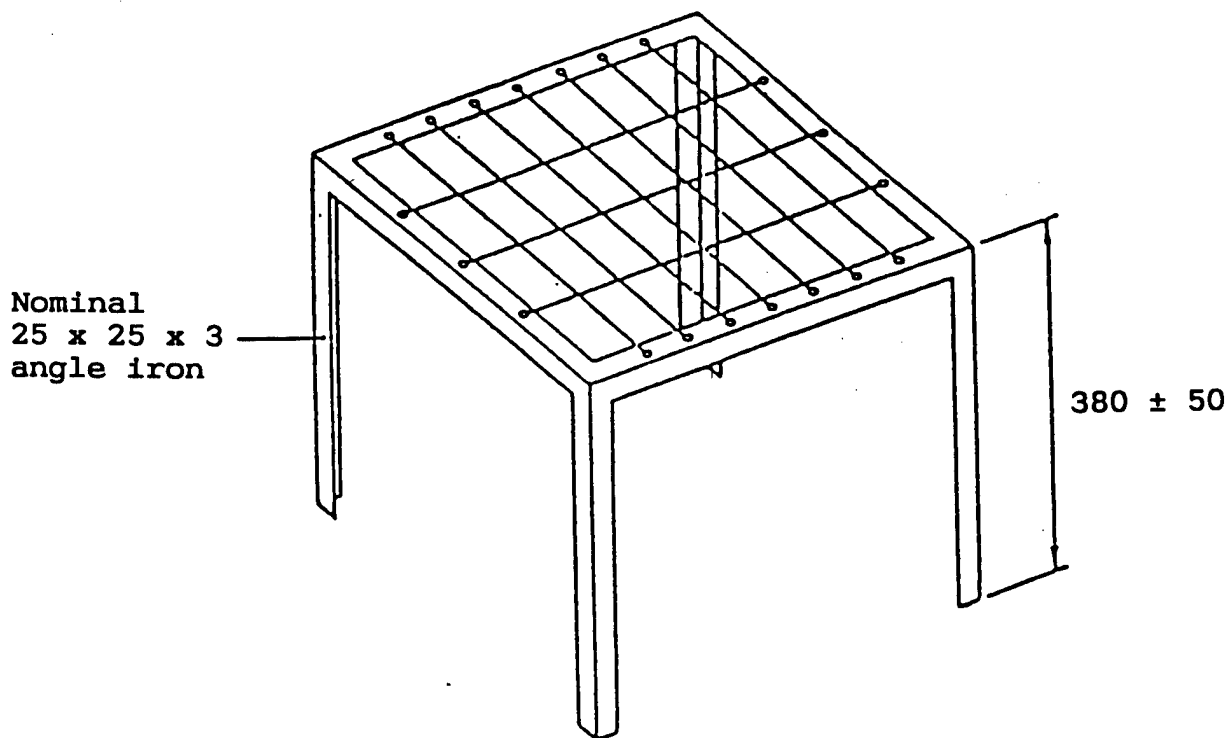
Progressive smoldering is a much different criteria than the length of char commonly used in the United States for ignition testing. Length of char can be defined very clearly with an exact prescription given for measurement. Progressive smoldering actually covers several responses to the ignition source including length of char. The other responses indicate a sustained or growing non-flaming combustion which may lead to a flaming combustion under different circumstances.

Test Method as Used In This Study

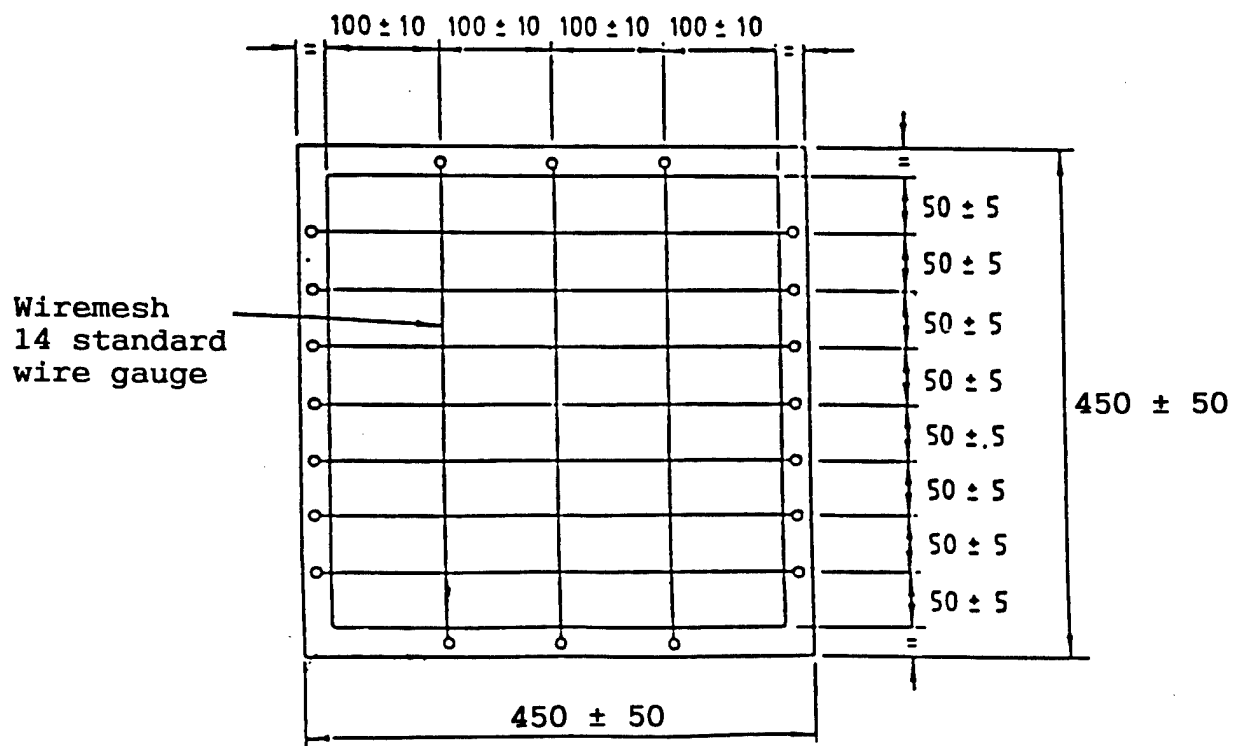
The method permits the use of either butane or propane to fuel the flaming ignition source. Propane was used in this series.

The proposed test method (Appendix A) was followed with minor exceptions. Section 6.3 of the proposed test method requires that flame retardant samples be cleansed three times before testing. This was considered unnecessary as the goal was to test the method, not to accept the product.

The legs of the test stand were shortened to 224 mm to fit the test stand into a fume hood. This was done to minimize the exposure of the test operator to smoke. The height of the test stand was specified as 380 ± 50 mm in the proposed standard. The working group revised the height to be 300 ± 150 mm in the final version of the standard (IMO Res. A.688(17)). Thus the test stand complies with the standard.



(a) Platform showing extended legs



(b) Spacing of wire mesh platform

All dimensions are in millimeters.

Figure 1. Diagram of the Test Stand

The cigarettes used in this study were 83 mm long. The proposed standard specifies that the cigarettes be 70 ± 4 mm long. The cigarettes (Pall Mall) met the standard in all other regards. The effect of the longer length may be that these tests were slightly more severe. In most cases, the length of char around the cigarette were uniform. Thus the longer length appears to have no effect on the results.

The proposed test method specifies two criteria for ignitability: progressive smoldering and flaming ignition. One of the types of behavior listed under progressive smoldering (Paragraph 7.1(e) of Annex A) is referred to in the U.S. as length of char. For this study, that behavior was reported separately as char and not smoldering. The length of char was measured from the cigarette.⁴

Test Samples

The selection of bedding components for testing was initially made by canvassing a half dozen hotels and motels to determine their sources of supplies. The most emphasis was placed on mattresses as they are the largest component and are already subjected to the federal fire test standard 16 CFR 1632. Blankets were given the least attention as wool had fared very well in previous upholstered furniture testing (See McLain, 1988). The initial selection was augmented by choosing specimens from the Federal Stock System to provide a wider selection. As described in Tables 1, 2, and 3, the final selection of components was

- 9 inner spring mattresses,
- 4 pillows,
- 1 pillow case,
- 5 sheets, and
- 2 synthetic blankets.

⁴ In the final revision, the working group revised or clarified that the length of char is to be measured from the edge of the cotton-wool pad. The author had interpreted the ignition source to be the cigarette whereas the working group's interpretation appears to be that the cotton-wool pad is an integral part of the ignition source (i.e., not just a covering).

Table 1. Description of Mattresses.

Sample No.	Description
1	- Mattress, spring unit covered C, 85% blended cotton felt treated with boric acid, 50% cotton linters, 50% cotton pickers, 15% resin treated fiber pad. Company A.
2	- Mattress, <i>Perm-a-lator</i> fire retardant synthetic pad, "Joy" cotton padding with 10% boric acid, spring unit covered C, 85% blended cotton felt treated with boric acid, 50% cotton linters, 50% cotton pickers, 15% resin treated fiber pad. Company A.
3	- Mattress, 74% blended felt - borax treated (100% cotton fibers), 26% polyurethane foam. Company B.
4	- Mattress, 64% blended felt with borax (100% cotton fibers), rubberized cover, 27% fiber pad, 9% polyurethane foam. Company B.
5	- Mattress, inner spring unit covered, 57% blend felt - borax treated (100% cotton fiber), rubberized cover, 23% fiber pad, 20% polyurethane foam. Company B.
6	- Mattress, inner spring unit covered, fire retardant, fire retardant ticking and fire retardant polyurethane foam. Company C.
7	- Mattress, 100% polyurethane foam. Company C.
8	- Mattress, vinyl covered, urethane foam 70%, cor fiber pad 30%, Company D.
9	- Mattress, fabric covered, urethane foam 70%, cor fiber pad 30%, Company D.
<p>All mattresses were inner spring. Linters are the short fibers clinging to cotton seeds after the first ginning. Pickers are the long fibers often referred to as long staple cotton.</p>	

Table 2. Description of Pillows.

Sample No.	Description
1	- Pillow, polyester fibers filling, antibacterial & flame retardant cover (vinyl 85%, Nylon 15%), Company E.
2	- Pillow, filling: 100% DACRON HOLLOFILL polyester, Company E.
3	- Pillow, crushed landfowl feather filling - chemically modified, cotton covering, Type IV, size 4, class 2, Federal Stock Code (FSC) 7210-01-015-5190
4	- Pillow, plastic polyester fiber filling, FSC 7210-00-019-5358

Table 3. Description of Blankets, Sheets, and Pillow Case.

Sample No.	Description
BLANKET	
1	- Blanket, 100% acrylic, Company E.
2	- Blanket, 100% polyester, Company E.
SHEET	
1	- Sheet, percale, type 180, white, 50% cotton, 50% polyester, Company E.
2	- Sheet, green flat, 100% cotton, Federal Stock Code (FSC) 7210-00-299-9611
3	- Sheet, green flat, 50% cotton, 50% polyester, non-spec., FSC 7210-00-199-7358
4	- Sheet, 70% polyester and 30% cotton sheet, local retail.
5	- Sheet, 100% polyester satin finish, local retail.
PILLOW CASE	
Case -pillow case, percale, type 180, white, 50% cotton, 50% polyester, Company E.	
Note: Percale is an opaque cotton fabric used to used to make sheets, pillowcases, and clothing.	

Testing Approach

The approach was to test various bedding components to the proposed test method and then test the ignitability of combinations of components. Setting up and testing to the proposed test method would provide the experience with the method. The testing of individual components would provide an estimate on how typical U.S. products would fare. The testing of combinations of components would provide an estimate of the effectiveness of the test method.

The testing of sheets resulted in additional issues being explored as they are widely used in the United States and the difficulty in finding one that would pass the proposed test method. This led to looking at the effects of different substrates and washing of the sheets.

RESULTS

The results of the testing are presented in five sections. The first section addresses how U.S. materials fared under the proposed test protocol. The second section addresses the effect of washing the sheets. The third section presents the results of exposing combinations of bedding components to the three ignition sources of the proposed test protocol and real-life scenarios. The fourth section addresses the appropriateness of the cotton-wool pad as a cover for the cigarette. The fifth section addresses the appropriateness of mineral wool as a substrate.

Performance Of U.S. Materials

The performance of U.S. mattresses, pillows, sheets, and blankets under the proposed test procedure is presented in Table 4. The ignition sources are numbered per the index in the table. The number of samples meeting the acceptance criteria (e.g., no ignition) for each ignition source is listed below the ignition source. All samples met the acceptance criteria for the cigarette covered by cotton fabric (ignition source 1). The number of samples passing the proposed standard (i.e., all three ignition sources) is indicated under the heading "1&2&3." The same samples met the acceptance criteria for the combination of the cotton-wool-covered cigarette and flame (2&3).⁵

⁵ This is the combination of ignition sources that the Subcommittee on Fire Protection accepted. They deleted the cigarette covered by cotton fabric.

Table 4. Number of Samples Passing Ignition Sources.

IGNITION SOURCES: 1 - Cigarette covered by cotton fabric
2 - Cigarette covered by cotton wool pad
3 - Flame

Component	Number of Samples	Ignition Sources					
		1	2	3	1&2&3 ¹	1&3 ²	2&3 ³
MATTRESS	9	9	3	4	1	4	1
PILLOW	4	4	2	1	1	1	1
SHEET	5	5	1	1	1	1	1
BLANKET	2	2	0	0	0	0	0

¹ 1&2&3 represents all three ignition sources in succession.

² 1&3 represents fabric-covered cigarette and flame in succession.

³ 2&3 represents wool-covered cigarette and flame in succession.

The performance of individual samples is presented in Tables 5 through 8. The length of char as measured from the edge of the cigarette is given in millimeters (mm) after the label "char."⁶ All samples passed the acceptance criteria for the fabric-covered cigarette. There is no apparent relationship between resistance to smoldering and flaming ignition sources.

Table 5. Test Results for Blankets.

#	Cigarette Covered By		Flame	Comments
	Fabric	Pad		
1	Pass	char (42 mm) ¹	flaming	acrylic
2	Pass	char ²	flaming	polyester

¹ Length of char as measured from the edge of the cigarette.

² Charred under entire cotton wool pad.

⁶ The revised test procedure specifies that the length of char is measured outward from the edge of the cotton wool pad. Those samples listed as failing due to length of char that would have met the revised criteria for the cigarette covered by the cotton wool pad.

Table 6. Test Results for Mattresses (all inner spring).				
#	Cigarette Covered By		Flame	Comments
	Fabric	Pad		
1	Pass	smoldering	Pass	fabric cover, cotton pad
2	Pass	smoldering	Pass	fabric cover, synthetic pad
3	Pass	smoldering	flaming	fabric cover, cotton felt
4	Pass	char (30 mm) ¹	flaming	rubberized cover, cotton felt
5	Pass	char (40 mm) ¹	flaming	rubberized cover, cotton felt
6	Pass	smoldering	Pass	fabric cover, polyurethane foam
7	Pass	Pass	flaming	fabric cover, polyurethane foam
8	Pass	Pass	Pass	vinyl cover, urethane foam
9	Pass	Pass	flaming	fabric cover, urethane foam
¹ Length of char as measured from the edge of the cigarette.				

Table 7. Test Results for Pillows.				
#	Cigarette Covered By		Flame	Comments
	Fabric	Pad		
1	Pass	Pass	Pass	vinyl cover, polyester filled
2	Pass	char (40 mm) ¹	flaming	fabric cover, polyester filled
3	Pass	char ²	flaming	fabric cover, feather filled
4	Pass	Pass	flaming	plastic cover, polyester filled
¹ Length of char as measured from the edge of the cigarette.				
² Charred under entire cotton wool pad.				

Table 8. Test Results for Sheets.				
#	Cigarette Covered By		Flame	Comments
	Fabric	Pad		
1	Pass	char (30 mm) ¹	flaming	cotton/polyester
2	Pass	char (30 mm) ¹	flaming	100% cotton
3	Pass	char (30 mm) ¹	flaming	cotton/polyester
4	Pass	char (27 mm) ¹	flaming	polyester/cotton
5	Pass	Pass (24 mm) ¹	Pass	100% polyester
¹ Length of char as measured from the edge of the cigarette.				

Table 9. Effect of Washing Sheets.				
#	Condition	Cigarette Covered By		Flame
		Fabric	Pad	
1	unwashed	Pass (5 mm) ¹	char (30 mm) ¹	flaming
	washed	Pass (5 mm) ¹	Pass (20 mm) ¹	flaming
2	unwashed	Pass (2 mm) ¹	char (30 mm) ¹	flaming
	washed	Pass (10 mm) ¹	char (38 mm) ¹	flaming
3	unwashed	Pass (7 mm) ¹	char (30 mm) ¹	flaming
	washed	--	--	flaming
¹ Length of char as measured from the edge of the cigarette.				
-- Not tested.				

Effect of Washing of Sheets

The goal of washing the sheets was to determine if the ignitability of the sheets was being affected by residue from the manufacturing process. Each sheet was washed three times with a household laundry detergent. Sheets 4 and 5 were obtained after conclusion of this testing. Table 9 on the preceding page shows that the results are inconsistent.

Performance Of Combinations of Bedding Components

Table 10 presents the results of exposing a sheet over a mattress to the smoldering ignition sources. The char lengths reported in Table 10 are the maximums observed of two runs. The results of the components tested individually are repeated for

convenience. The char lengths observed for the combination are greater than that observed for the individual items. For the combination, the char on the mattress was more extensive than that of the sheet for both smoldering ignition sources.

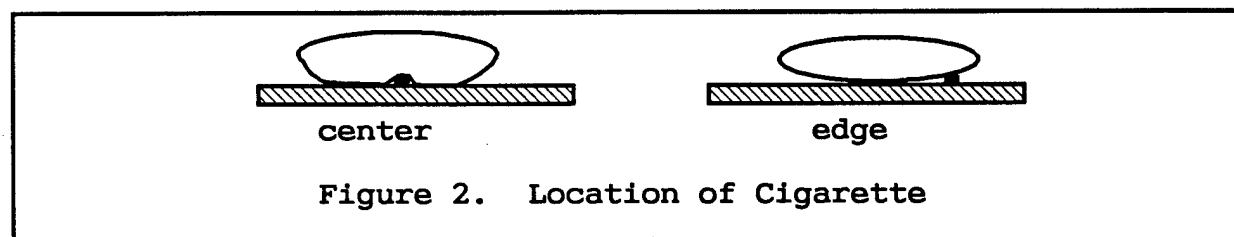
Under the revised standard, all of the results (combination and individual) would be acceptable. Please remember that Mattress #8 performed very well in comparison to the other mattresses. The result might have been obvious progressive smoldering or flaming if a less resistant mattress had been used.

Table 10. Sheet Over Mattress Exposed to Smoldering Ignition Sources.				
Sample	Cigarette Covered By			
	Cotton Fabric		Cotton Wool Pad	
	Combination	Individual	Combination	Individual
Sheet #1	Pass (9 mm)	Pass (5 mm)	char ¹	char (30 mm)
Mattress #8	Pass (14 mm)	Pass (4 mm)	char ²	Pass (15 mm)
¹ Charred under entire cotton wool pad. ² Char extended 13 mm beyond the charred area of sheet and the cotton wool pad.				

Sheets and blankets over two mattresses were exposed to the flaming ignition source. The results are presented in Table 11. When test individually, only mattress #8 and sheet #5 passed all aspects of the proposed standard. The combination of the two also passed the flaming ignition source. Three samples passed when tested over mattress #8 even though they failed the flaming ignition source when tested over mineral wool per the proposed standard. A mattress resistant to ignition by flame may provide some benefit even though the other components are not as resistant.

A single combination of mattress and pillow was tested for the scenario of a cigarette between the pillow and mattress. Additional combinations were not tried due to the variability of the results. The combination consisted of Mattress #8 and Pillow #1; both met all aspects of proposed standard when tested singly. Two trials were conducted with the cigarette centered between the mattress and pillow. Four trials were conducted with the cigarette placed near the edge of the pillow and mattress (see Figure 2). With the cigarette in the center, the charred area on

Table 11. Sheets and Blankets Over Mattresses Exposed to Flaming Ignition Source.			
Sample	Proposed Standard	Tested Over Mattress	
		#5	#8
Mattress #5	flaming	--	--
Mattress #8	Pass	--	--
Sheet #1	flaming	--	flaming
Sheet #1 washed	flaming	flaming	Pass
Sheet #2 washed	flaming	flaming	flaming
Sheet #3 washed	flaming	flaming	flaming
Sheet #4	flaming	flaming	Pass
Sheet #5	Pass	flaming	Pass
Blanket #1	flaming	flaming	flaming
Blanket #2	flaming	Pass	Pass
-- Not tested.			



both the pillow and mattress extended less than 1 mm past the cigarette. The cigarettes were smothered by the melting of the vinyl ticking of the pillow and mattress. With the cigarette at the edge, the size of the charred area varied considerably but did not exceed 78 mm by 17 mm. This is less of a charred area than exhibited by either mattress or pillow when exposed to the cigarette covered by the cotton wool pad per the proposed standard.

The combination of pillow and pillow case was tested under the proposed standard as pillows are generally covered by a pillow case in use. As described in Table 3, the case is made of the same cotton-polyester percale as Sheet #1. The results are presented in Table 12. In general, the presence of the case reduced the area of char. This is just the opposite of the effect that Sheet #1 had with Mattress #8 (see Table 10).

Table 12. Effect of Pillow Cases For Pillows.			
Condition	Cigarette Covered By		Flame
	Fabric	Pad	
Pillow 1 without case with case	Pass Pass	Pass (15 mm) Pass (15 mm)	Pass Pass
Pillow 2 without case with case	Pass Pass	char (40 mm) ¹ Pass (20 mm)	flaming flaming
Pillow 3 without case with case	Pass Pass	char ² char (70 mm) ¹	flaming flaming
¹ Length of char as measured from the edge of the cigarette.			
² Charred under entire cotton wool pad.			

Cover for Cigarette in Smoldering Ignition Sources

A quick check of the realism of the covers used for covering the cigarette was made by using Blanket #1 as a cover. The results are presented in Table 13. The cigarette was placed between the mattress and the blanket. Each test was repeated twice with the reported value in Table 13 being the maximum char length of the two runs. The results of the items tested per proposed standard are repeated for convenience. The observed char lengths for the blanket-covered cigarette are similar to those observed for the fabric covered cigarette of proposed standard. This suggests that both smoldering ignition sources appear to be reasonable.

Table 13. Cigarette between Mattress and Blanket.			
Sample	Cigarette Covered By		
	Fabric	Pad	Blanket #1
Mattress #4	Pass (10 mm)	char (30 mm)	10 mm ¹
Mattress #8	Pass (4 mm)	Pass (15 mm)	3 mm ²
Blanket #1	Pass (7 mm)	char (42 mm)	not tested
¹ Length of char as measured from the edge of the cigarette.			
² Char length on blanket (#1) was 7 mm.			
² Char length on blanket (#1) was 6 mm.			

Mineral Wool As A Substrate

In the attempt to find a sheet to pass the proposed standard, the question of the appropriateness of mineral wool as a substrate arose. The results of a comparison between mineral wool and cotton wool substrate using a 100% cotton sheet (sheet #2) are presented in Table 14. In both cases, the char length increased with a cotton wool substrate. When a cotton wool pad was used to cover the cigarette, the cotton wool substrate smoldered. Whether this would occur with all sheets and blankets is not clear.

Table 14. Mineral Wool Versus Cotton Wool as a Substrate. (Test sample was Sheet #2.)		
Substrate	Cigarette Covered By	
	Fabric	Pad
Mineral wool	Pass (2 mm)	char (30 mm) ¹
Cotton wool	Pass (4 mm)	char ²
¹ Length of char as measured from the edge of the cigarette. ² Entire area under the cotton wool pad charred.		

Results under IMO Res. A.688(17)

The ignition source of the cigarette covered by a fabric (ignition source #1 of Table 4 on page 9) was not included in the adopted resolution, IMO Res. A.688(17). This does not change the results as none of the test specimens was ignited by that ignition source.

For the cigarette covered by the cotton wool pad (ignition source #2), the permissible length of char was increased to be 25 mm from the edge of the cotton wool pad. As shown in Table 15, this increases the number of test specimens that passed this ignition source.

The overall results under IMO Res. A.688(17) are shown in Table 16. While more of the samples passed ignition source 2, the overall results of the combination of ignition source 2 and 3 are the same.

Table 15. Number of Samples Passing the Two Versions of Criteria for the Cigarette Covered by the Cotton Wool Pad (Ignition Source 2)			
Component	Number of Samples	Proposed Standard	IMO Res. A.688(17)
MATTRESS	9	3	5
PILLOW	4	2	4
SHEET	5	1	5
BLANKET	2	0	2

Table 16. Number of Samples Passing Ignition Sources under IMO Res. A.688(17).				
IGNITION SOURCES: 2 - Cigarette covered by cotton wool pad 3 - Flame				
Component	Number of Samples	Ignition Sources		
		2	3	2&3 ³
MATTRESS	9	5	4	1
PILLOW	4	4	1	1
SHEET	5	5	1	1
BLANKET	2	2	0	0
³ 2&3 represents wool-covered cigarette and flame in succession.				

SUMMARY

All of the test specimens passed the ignition source of cigarette covered by fabric.

The most severe combination of ignition sources are the cigarette covered by a cotton wool pad and the flame. This is the same in the proposed standard and the version adopted as IMO Res. A.688(17).

Using the revised criteria in IMO Res. A.688(17), all test specimens that failed due to length of char would have passed the cigarette covered by a cotton wool pad.

REFERENCES

McLain, William H. 1988. Evaluation Of IMO Preliminary Draft Recommendation On Fire Test Procedures For Upholstered Furniture (FP 32/WP.9 Annex 6), U. S. Coast Guard, Report No. CG-M-5-89.

Thompson, CAPT Thomas E. 1990. "International maritime procedures," Proceedings of the Marine Safety Council, 47 (Sep. - Oct.): 23-26

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APPENDIX A

**Proposed Test Method as Contained in Annex 4 of FP34/WP.7/Add.1
and Annex 6 of FP34/23.**

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ANNEX 6

IGNITABILITY OF BEDDING COMPONENTS

INTRODUCTION

The test specified in this method deals with a simple presentation of a particular aspect of the potential fire situation typified by smouldering cigarettes and a match equivalent flame exposure to the product. The test alone cannot provide any direct guidance on behaviour or safety in other types of accidents, like exposure to larger sources of flames. A test of this type may, however, be used to make comparisons or to ensure the existence of a certain characteristic considered to have a bearing on fire performance in general. No other significance should be attached to performance in this test. The attention of all users of the test is drawn to the following warning:

SAFETY WARNING. IN ORDER THAT SUITABLE PRECAUTIONS MAY BE TAKEN TO SAFEGUARD HEALTH, THE ATTENTION OF ALL ENGAGED WITH FIRE TESTING IS DRAWN TO THE FACT THAT TOXIC OR HARMFUL GASES MAY BE RELEASED DURING COMBUSTION OF TEST SPECIMENS.

1 SCOPE

The method specifies a procedure to determine the ignitability of bedding components with small smouldering and flaming sources of ignition.

2 FIELD OF APPLICATION

The method is intended for testing blankets, quilts, pillows and mattresses, including thin, light mattresses used on top of other mattresses.

3 REFERENCE

British Standard BS 6807:1986

British Standard Method of test for the ignitability of mattresses with primary and secondary sources of ignition.

ISO/TC 38/SC 19/N 239: Terms and definitions.

4 DEFINITIONS

Mattress: Product in the form of a resilient material (for instance polyurethane foam or light fibre fill) or of padding materials in combination with steel springs (spring mattress), enveloped by a cover.

Quilt and pillow: Products of padding materials (down/feather or textile fibre) enveloped by a textile fabric.

Ticking: Fabric enveloping the resilient material in a mattress.

Ignitability: A measure of the ease with which a material or a product can be ignited so as to flame or progressively smoulder.

Ignition source: Source of energy which is used to ignite combustible materials or products.

Flaming: Undergoing combustion in the gaseous phase, usually with emission of light.

Smouldering: An exothermic reaction taking place in a material without flaming, with or without emission of light.

Progressive smouldering: Smouldering which continues after the ignition source is extinguished or removed.

5 SAMPLING

The specimens shall be representative of the whole product to be tested. If possible, the specimens shall be taken in such a way that ignition can also be started along seams and their intersections.

The top side is exposed. Where there is doubt as to which side is the top side, the test shall be carried out on both sides. Six additional specimens are then needed.

Mattresses: Sufficient material shall be available for making at least 6 specimens with dimensions 450 mm x 350 mm in full nominal thickness. The cover shall envelope the mattress completely without wrinkles, and it shall be secured underneath (for instance with steel pins).

For testing of mattresses with removable covers, sufficient material shall be available for the making of at least 12 specimens, 6 with and 6 without the mattress cover, with dimensions 450 mm x 350 mm in full nominal thickness.

Pillows: Four samples in full size shall be available.

Other than mattresses and pillows: Six specimens each of size 450 mm x 350 mm are cut from each sample.

If the product contains loose filling material, the edges must be sewn. It is advisable to sew the seams before cutting the specimens in order to avoid loss of filling material.

6 TEST METHOD

6.1 Principle

The test is carried out with the specimen placed in a horizontal position on a test rig. The ignition source is placed on top of the specimen. The determination of the ignitability is carried out using smouldering and flaming ignition sources. A smouldering cigarette covered with an insulating fabric

is used as primary smouldering ignition source. A smoulderable insulation of cotton wool on a smouldering cigarette is used as secondary smouldering ignition source, which is intended to simulate possible smoulderable materials used in bedding.

The flaming ignition source is a small butane or propane flame.

The ignition of the specimen in progressive smouldering or flaming is observed.

6.2 Apparatus and material

The following equipment and material are necessary for the test:

- (a) The test rig for support of the specimen is shown in figure 1. The stand is made of angle iron with nominal dimensions 25 mm x 25 mm x 3 mm. On top of the stand is a platform of wire mesh with openings of nominal dimensions 100 mm x 50 mm.
- (b) Mineral wool with a nominal density of 60 kg/m^3 and with dimensions 450 mm x 350 mm x 50 mm.
- (c) Stock clock.
- (d) Test enclosure, being either a room with a volume greater than 20 m^3 (which contains adequate oxygen for testing), or a smaller enclosure with a through flow of air. Inlet and extraction systems providing air flow rates of 0.2 m/s to 0.2 m/s in the locality of the rig provide adequate oxygen without disturbing the burning behaviour.
- (e) Ignition sources. The sequent ignition sources used are a smouldering cigarette covered with a piece of cotton fabric, a smouldering cigarette covered with a cotton wool pad and an open flame.

- (f) Cigarette. For the tests, cigarettes with the following specifications shall be used:

Length: 70 ± 4 mm
Diameter: 8 ± 0.5 mm
Weight: 1 ± 0.1 g
Smouldering rate: 12 ± 3 minutes/50 mm

The smouldering rate shall be verified for every collection of 200 cigarettes as follows:

The cigarettes are conditioned as described below under 6.4. -- One cigarette is marked at distances 5 mm and 55 mm from one end. The cigarette is ignited at the end with the 5 mm distance marking, and the air is drawn through the cigarette until a clear glow is observed, but not further than on to the 5 mm marking, whereafter the cigarette is impaled horizontally on a wire spike inserted not more than 13 mm into the unlit end. The time is recorded for the smouldering from the 5 mm to the 55 mm marks.

- (g) Cotton fabric. The cigarette shall be covered with a piece of cotton fabric plain weave of weight 150 ± 20 g/m², with dimensions 150 mm x 150 mm.
- (h) Cotton wool pad. The cigarette shall be covered with a pad of cotton wool of nominal dimensions 150 mm x 150 mm x 25 mm and of weight 20 ± 6.5 g. The piece shall be unwrapped from the roll as a single layer 25 mm to 30 mm thick, cut to plan size, then reduced to the correct mass and thickness by removal of loose fibres from the top.
- (i) Flame. The burner is a tube of stainless steel with internal diameter 6.5 ± 0.1 mm, outside diameter 8 ± 0.1 mm and length 200 mm. The fuel may be butane or propane gas. Fuel supply rate:

$6.38 \text{ g} \pm 0.25 \text{ g/hour at } 20^\circ\text{C}$

6.3 Preparation of specimens

If the blankets, quilts, pillows, thin, light mattresses or removable covers are sold as flame retarded, they shall be tested after three cleansing treatments carried out according to instructions given by the manufacturer or in accordance with a procedure described in International Standard ISO 6330.

6.4 Conditioning

The materials to be tested, the cigarettes used as ignition sources, the insulating cotton fabric and cotton wool pads shall be conditioned immediately before testing for 72 hours in indoor ambient conditions and then for at least 16 hours in an atmosphere having a temperature of $23 \pm 2^{\circ}\text{C}$ and $50 \pm 5\%$ relative humidity.

6.5 Test procedure

The test is carried out indoors, in an environment essentially free of air currents. The room temperature shall be $20 \pm 5^{\circ}\text{C}$.

The mattress specimen is placed directly on the test rig. The blanket, pillow, quilt and thin, light mattress specimen is placed on the mineral wool which is laid on the test rig. The ignition source is placed on top of the specimen. The time is measured from the moment the ignition source is placed on the specimen.

The test duration is one hour from the moment the ignition source is placed on the specimen.

6.5.1 Testing with smouldering ignition sources

The cigarette is lighted and air is drawn through the cigarette until it glows brightly. Not less than 5 mm and not more than 8 mm of the cigarette shall be consumed in this operation. The cigarette is placed on the specimen at a distance of at least 100 mm from the nearest edge of the specimen or from marks left by any previous test. The cotton fabric or the cotton wool pad is placed centrally on the cigarette, and the clock is started.

The progress of combustion is observed and any evidence of progressive smouldering ignition (see 7.1) or of flaming ignition (see 7.2) of the specimen is recorded.

Two separate tests are carried out with the cigarette covered with cotton fabric and cotton wool pad respectively.

On specimens with stitchings, one test is carried out with the cigarette placed along a stitching, and one test is carried out with the cigarette placed on a smooth surface if possible.

6.5.2 Testing with flame as ignition source.

The gas is ignited and the gas flow adjusted to appropriate rate (reference 6.2(i)). The flow is allowed to stabilize for at least 120 seconds. The burner is placed horizontally on the specimen at a distance of at least 100 mm from any edge of the specimen and not less than 50 mm from any marks left from previous tests.

The specimen shall be exposed to the ignition flame for 20 seconds. The exposure is terminated by carefully removing the burner from the specimen.

The progress of combustion is observed and any evidence of progressive smouldering ignition (see 7.1) or of flaming ignition (see 7.2) of the specimen is recorded.

Two separate tests are carried out

On specimens with stitchings, one test is carried out with the burner placed along a stitching, and one test is carried out with the burner placed on a smooth surface if possible.

6.6 Expression of test results

6.6.1 All time observations are expressed in minutes and seconds elapsed from the start of the test. The test results include:

- the behaviour of the specimen during and immediately after the specified test period;
- flames or detectable amounts of smoke, heat or glowing during and immediately after the specified test period;
- damages to the specimen after the test is finished, measured in mm.

6.6.2 The results obtained from each individual test shall be reported separately.

6.7 Test report

The test report shall contain the following information:

- (a) name and address of the testing laboratory;
- (b) date and identification number of the report;
- (c) name and address of the client;
- (d) purpose of the test;
- (e) method of sampling;
- (f) name of manufacturer or supplier of the product;
- (g) name or other identification marks and description of the product;
- (h) density and thickness of the product;
- (i) date of supply of the product;
- (j) description of the specimens and preparation technique;
- (k) date of test;
- (l) test method;

- (m) conditioning of the specimens;
- (n) deviations from the test method, if any;
- (o) test results;
- (p) designation of the product according to criteria expressed in official standards or regulations.

7 CRITERIA FOR IGNITABILITY

7.1 Progressive smouldering

For the purpose of this test method, all the types of behaviour described below in (a) to (e) are considered to be progressive smouldering ignition:

- (a) Any test specimen that produces externally detectable amounts of smoke, heat or glowing after a period of one hour following the application of the ignition source.
- (b) Any test specimen that displays escalating combustion behaviour so that it is unsafe to continue the test and requires forcible extinction.
- (c) Any test specimen that smoulders until it is essentially consumed within the duration of the test.
- (d) Any test specimen that smoulders to the extremities of the specimen, viz. to either side or to the full thickness of the specimen, within the duration of the test. However, all thin materials, like thin, light mattresses, quilts and blankets are allowed to smoulder to the full thickness of the specimen.
- (e) Any test specimen that, on final examination, shows evidence of smouldering other than discoloration more than 25 mm in any horizontal direction from the nearest part of the original position of the ignition source.

7.2 Flaming ignition

7.2.1 Mattresses:

For the purpose of this test method, all the types of behaviour described below in (a) to (e) are considered to be flaming ignition.

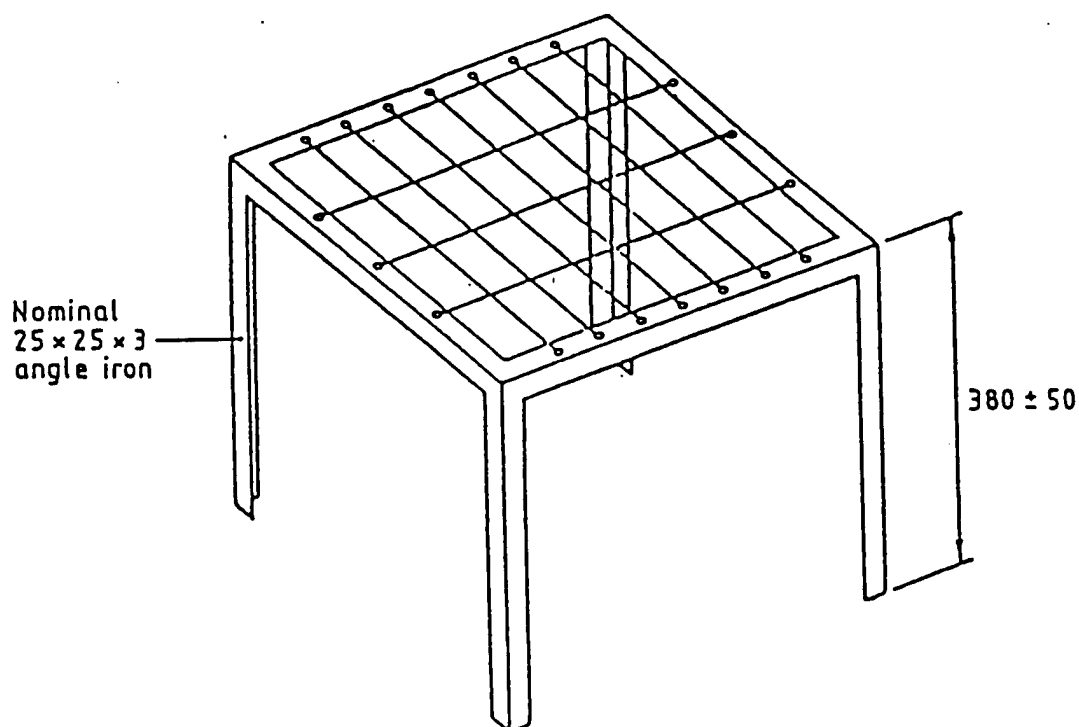
- (a) The occurrence of any flames initiated by a smouldering cigarette.
- (b) Any test specimen that continues to flame for more than 150 seconds from removal of the igniting flame.
- (c) Any test specimen that displays escalating combustion behaviour, so that it is unsafe to continue the test and requires forcible extinction.
- (d) Any test specimen that burns until it is essentially consumed within 150 seconds from removal of the igniting flame.
- (e) Any test specimen that burns to the extremities of the specimen, viz. to either side or to the full thickness of the specimen, within the duration of the test.

7.2.2 Blankets, quilts, pillows and thin, light mattresses:

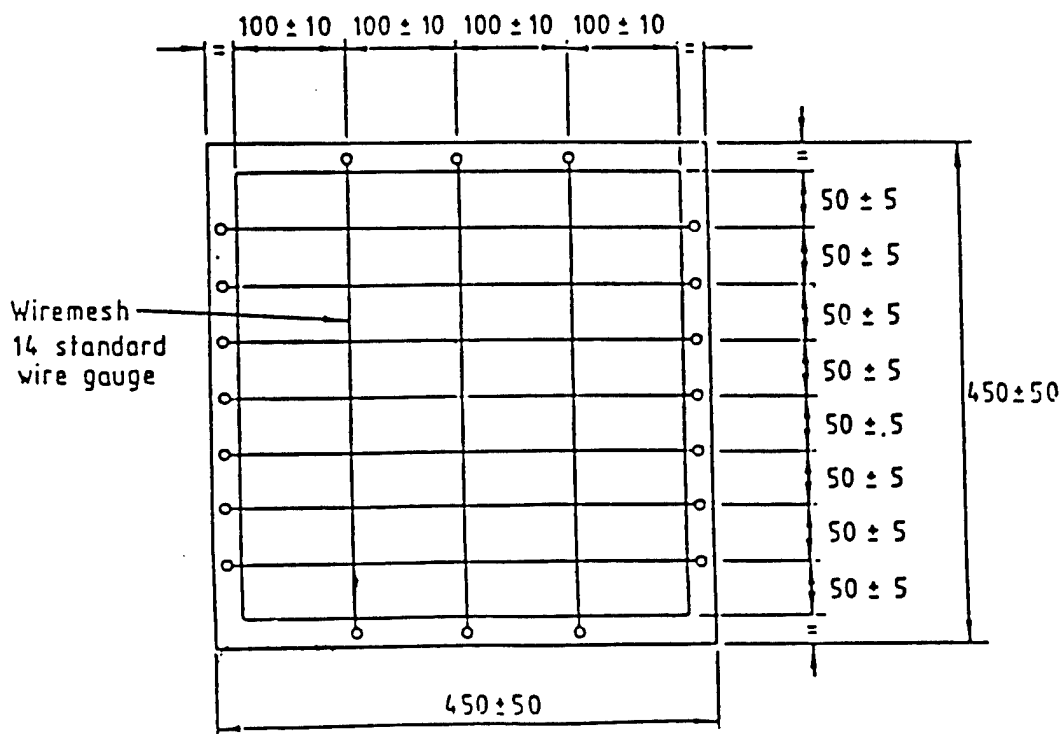
For the purpose of this test method all the types of behaviour described below in (a) to (e) are considered to be flaming ignition.

- (a) The occurrence of any flames initiated by a smouldering cigarette.
- (b) Any test specimen that continues to flame for more than 150 seconds from removal of the igniting flame.
- (c) Any test specimen that displays escalating combustion behaviour, so that it is unsafe to continue the test and requires forcible extinction.

- (d) Any test specimen that burns until it is essentially consumed within 150 seconds from removal of the igniting flame.
- (e) Any test specimen that burns to either side of the specimen within the duration of the test.



(a) Platform showing extended legs



(b) Spacing of wire mesh platform

All dimensions are in millimetres.